An assessment of the validity of the remote food photography method (termed Snap-N-Send) in experienced and inexperienced sport nutritionists

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ABSTRACT

The remote food photography method (RFPM), often referred to as 'Snap-N-Send' by sport nutritionists, has been reported as a valid method to assess energy intake in athletic populations. However, preliminary studies were not conducted in true free-living conditions and dietary assessment was performed by one researcher only. We therefore assessed the validity of 'Snap-N-Send' to assess energy and macronutrient composition in experienced (EXP, n=23) and inexperienced (INEXP, n=25) sport nutritionists. Participants analysed two days of dietary photographs, comprising eight meals. Day 1 consisted of 'simple' meals based around easily distinguishable foods (i.e. chicken breast and rice) and Day 2, 'complex' meals containing 'hidden' ingredients (i.e. chicken curry). Estimates of dietary intake were analysed for validity using one-sample t-tests and typical error of estimates (TEE). INEXP and EXP nutritionists underestimated energy intake for the simple day (Mean difference, MD = -1.5 MJ, TEE = 10.1%; -1.2 MJ, TEE = 9.3% respectively) and the complex day (MD = -1.2 MJ, TEE = 17.8%; MD = -0.6 MJ, 14.3% respectively). Carbohydrate intake was underestimated by INEXP (MD = -65.5 $g.day^{-1}$, TEE = 10.8% and MD = -28.7 $g.day^{-1}$, TEE = 24.4%) and EXP (MD = -53.4 $g.day^{-1}$, TEE = 10.1% and -19.9 $g.day^{-1}$, TEE = 17.5%) for both simple and complex days, respectively. The inter-practitioner reliability was generally 'poor' for energy and macro-nutrients. Data demonstrate that the RFPM / ‘Snap-N-Send’ under-estimates energy intake in simple and complex meals and these errors are evident in experienced and inexperienced sport nutritionists.

Key words: dietary intake, exercise, RED-S, LEA

INTRODUCTION

A fundamental activity for sport nutritionists is to estimate energy and macronutrient intake from an athlete's self-reported food intake (Braakhius et al., 2003). Such dietary assessments are important given the role of energy and macronutrient intake in modulating training adaptation (Impey et al., 2018), body composition (Kasper et al., 2018; Morton et al., 2010; Wilson et al., 2015) and exercise performance (Burke & Hawley 2018). Additionally, nutrient availability can also play a fundamental role in growth and maturation (Hannon et al., 2020), mental health (Wilson et al., 2014) and reducing the risk of illness and injury (Kasper et al., 2018; Walsh, 2019; Wilson et al., 2014). Despite the clear rationale to accurately assess an athlete's energy intake, this remains a major methodological challenge that is fraught with sources of error on both the athlete's and sport nutritionist's part (Capling et al., 2017).

Broadly speaking, dietary assessment methods are classified as 'retrospective' (including 24-hour recall, food frequency questionnaires, diet histories) or 'prospective' (including food diaries with / without weighed inventory). Inaccuracies are inherent with self-reported dietary assessments and include the misreporting of food consumption alongside measurement error (Gemming et al., 2014; Rollo et al., 2016; Westerterp et al., 1986). Furthermore, most of the dietary assessment methods are logistically complicated, especially when assessing multiple athletes (e.g. sports teams) in free living conditions (Martin et al., 2012). Validity and precision, in addition to practitioner and participant burden, are cited as some of the main causes of inaccuracies in dietary assessment (Livingstone & Black, 2003; Thompson et al., 2010). In addition to the bias associated with participant burden and self-reporting, the requirement of accurate unbiased interpretation by a nutritionist or dietitian has led to the criticism within the sports nutrition community that systematic error in dietary analysis is neglected and somewhat overlooked (Kirkpatrick & Collins, 2016).

In an attempt to improve participant reporting accuracy in traditional pen and paper methods, Martin et al. (2009) developed the remote food photograph method (RFPM) whereby participants record dietary intake in real time via ecological momentary assessment. In this approach, participants take and transmit photographs (via camera enabled cell phones with data transfer capability) of food selection and plate waste to researchers for subsequent dietary analysis. In combining the principles of the RFPM with elements of behavioural change science to engage participants and all key stakeholders, Costello et al. (2017) subsequently developed the 'Snap-N-Send' methodology demonstrating that an athletic population was also capable of adhering to self-reporting of dietary intake via smart phone technology. However, whilst this preliminary study concluded that ‘Snap-N-Send’ was valid and reliable as a standalone dietary assessment method, there are several limitations that should be noted. First, the experimental conditions were not true free-living, given that participants were restricted to consuming foodstuffs that were provided by the researchers during the study period. In this way, the researcher had prior knowledge of approximate portion sizes and macronutrient profile of the foods consumed given that foods were weighed by the research team before being distributed to the participants. Second, the subsequent dietary analysis was performed by one researcher only, an important methodological factor considering the inherent variability that exists between experienced sports dieticians when coding food records for analysis (Braakhius et al., 2003). Thus, the aim of the present study was to assess the validity of utilising the RFPM / ‘Snap-N-Send’ as a standalone method to assess energy and macronutrient composition in experienced and inexperienced sport nutritionists.

METHODS

Participants

Forty-eight participants were recruited to take part in this study. Participants were non-randomly allocated to two independent groups based upon the inclusion criteria: 1) Recent Sport and Exercise Nutrition register (SENr) graduates with graduate accreditation status (n=25) [termed INEXPERIENCED]; or 2) Full SENr practitioner registrants with >3 years working within elite sport (n=23) [termed EXPERIENCED]. All of the 'inexperienced' sport nutritionists had received recent training in dietary assessment (including the RFPM) from experienced sport nutritionists whilst all of the 'experienced' sport nutritionists, as a criteria of their SENr registration, will have demonstrated evidence of competency in dietary assessment. This study was approved by the university ethics committee (M20_SPS_767) and was conducted in accordance to the Declaration of Helsinki.

Study Design

Participants were provided with the same two days of dietary images comprising of a total of eight meals (breakfast, morning snack, lunch and evening meals). These foods, photographed remotely, had been compiled by the research team with one day being classed as 'simple' meals and the second day being 'complex' meals with the two days being similar in total energy content. Dietary images and short descriptions were then sent to each participant via email or over a free cellular picture messaging smartphone application (WhatsApp Inc., California, USA) for analysis. Participants were asked to analyse each meal for its calorific and macronutrient content using Nutritics dietary analysis software using the pre-set UK/Ireland database (Nutritics version 5.5, Swords, Ireland) and return these data files to the primary researcher to assess the ability of experienced and inexperienced practitioners to estimate energy intake in comparison to food labels.

Control

To standardise perceived portion size, all meals were placed on the same plate or bowl with cutlery on a 1 x 1 cm A3 reference grid placemat as previously described (Costello et al., 2017). All images were taken by the researcher at a height of sixty centimetres at a ninety-degree angle. Images were later cropped so that the reference grid filled the image (15.01 cm x 21.34 cm) and added to a standard PowerPoint slide (19.05 cm x 25.4 cm) with a brief description of the food in the image (e.g. Weetabix cereal made with semi-skimmed milk).

Meal Design

Day one of the diet diary was designed in a simplistic manner whereby each individual food item could be easily identified and distinguished by the participant, e.g. chicken breast and rice [termed SIMPLE]. In this day, no extras were added to meals such as butter on potatoes or condiments such as mayonnaise. The second day was designed to contain a number of complex meals whereby it was more difficult to ascertain a number of individual ingredients and definite quantities of each food item, e.g. chicken curry and rice [termed COMPLEX]. Again, no hidden extras were added. For the purpose of this study, it was presumed that all foods on the plate were consumed with no need to attempt to calculate the left-over food items. An overview of the meals and energy content can be found in Figure 1.

Statistical Analysis

Data were assessed for normality using standard graphical procedures and Shapiro-Wilk tests. Values of minimally clinically important difference (MCID) have not been used in this study because the use of hard anchors cannot be universally applied for each variable in multiple scenarios (Cook et al., 2014). For example, in an acute nutritional intervention, differences in energy intake of 0.5 $MJ.day^{-1}$ would have little effect but would likely be clinically important in a chronic setting. Likewise, a small change in nutrient content of diets that have very low total energy may be important, but in an athlete with much higher energy needs and intake, it will not be. Therefore, the effect sizes of Cohen's d (for t-tests) and r-values (for Wilcoxon signed rank tests) were used to help to determine the magnitude of potential differences. These effect sizes were interpreted as small, medium and large using the values of 0.2, 0.5, 0.8; and 0.1-<0.4, 0.4-<0.6, ≥0.6 for d and r respectively.

Consequently, differences between the actual nutrient data (as obtained from food labels), the estimated energy intake, the macronutrient content of the simple and complex days, and individual meals and daily snacks, were assessed using one sample t-tests or Wilcoxon signed rank tests where difference data were non-parametric. Differences in the observed dietary analysis data between the inexperienced and experienced groups were assessed using independent t-tests for the energy and macronutrient content of both the simple and complex days.

The validity of the observed data compared to the known nutrient values was assessed using coefficient of variation (CV) along with 95% limits of agreement (LoA), bias and 95% confidence intervals (CI). Coefficient of variation was interpreted using the following thresholds: <2% (excellent), <5% (good), <10% (acceptable), >10% (poor), >20% (very poor). Inter-rater reliability (termed inter-practitioner reliability hereafter) was assessed using a two-way mixed effects model for Cronbach's alpha, intra-class correlations (ICC) with 95% CI and CV. All inferential statistical tests and validity calculations were conducted using SPSS (v25 for Windows, Illinois, USA) MS Excel (365 for Windows, Washington, USA) respectively.

RESULTS

Estimated Dietary Intake

The inexperienced, experienced, and whole sample underestimated energy intake (Figure 2A and Table 2) for the simple day (MD = -1.7 MJ, w = 10.0, z = 4.1, $p < 0.001$, r = 0.58; MD = -1.2 MJ, $p < 0.001$, CI = -1.56, -0.81, d = 1.36 and MD = -1.4 MJ, $p < 0.001$, CI = -64, -1.10, d = 1.50; respectively) and the complex day (MD = -1.2 MJ, p = 0.001, CI = -1.80, -0.54, d = 0.76; MD = -1.5 MJ, w = 1140, z = 5.7, $p < 0.001$, r = 0.58; and, MD = -0.9 MJ, $p < 0.001$, CI = -1.32, -0.50, d = 0.65; respectively). The estimated energy intake values were not different between the groups for either the simple (MD = 0.35 MJ, p = 0.186, CI = -0.88, 0.18, d = 0.59) or complex days (MD = p = 0.185, CI = -1.35, 0.27, d = 0.39).

Estimated carbohydrate (CHO) intake (Figure 2B) was underestimated by the inexperienced (MD = -67.5 g, w = 324.0, z = 4.4, $p < 0.001$, r = 0.62; and, MD = -26.9 g, w = 217.0, z = 2.4, p = 0.016, r = 0.35), the experienced (MD = -53.4 g, , $p < 0.001$, CI = -62.7, -44.0, d = 2.73 and, MD = -64.2 g, w = 1174, z = 6.0, $p < 0.001$, r = 0.61) and whole sample (MD = -62.3 g, $p < 0.001$, CI = -68.8, -55.8, d = 2.79; and, MD = -24.5 g, $p < 0.001$, CI = -37.3. -11.64, d = 0.55) for both the simple and complex days respectively. There were again no differences in the carbohydrate estimates between the groups for either the simple (MD = 6.7 g, p = 0.308, CI = -19.6, 6.3, d = 0.30) or complex (MD = 8.8 g, p = 0.493, CI = -34.7, 17.0, d = 0.20) days.

Estimates of fat intake (Figure 2D) made by the inexperienced group were lower than the actual fat content of the simple day (MD = -6.7 g, w = 257.0, z = 2.5, p = 0.011, r = 0.36), but this was not the case for the experienced group (MD = -3.6g, p = 0.173, CI = -8.8, 1.7, d = 0.29, respectively), and there were no differences between the fat intake estimates of the two groups combined (MD = -4.2 g, p = 0.331, CI = -12.9, 4.4, d = 0.24). However, when two groups were combined for the whole sample, fat intake was under-estimated by a small amount (MD = -5.8 g, p = 0.010, CI = -10.1, -1.48, d = 0.39).

Fat intake estimates for the complex day were not different from the actual value for either the inexperienced (MD = 5.38 g, p = 0.059, CI = -10.9, 0.22, d = 0.39), experienced (MD = 3.95 g, p = 0.183, CI = -2.0, 9.9, d = 0.29), or whole sample (MD = -1.0 g, p = 0.630, CI = -5.2, 3.2, d = 0.08). However, the inexperienced group estimated fat intake to be lower than that of the experienced group for the complex day (MD = -9.3 g, p = 0.023, CI = -17.3, -1.4, d = 0.69).

The estimations of protein intake were not different between the two groups (Figure 2C), for either the simple or complex days

(MD = 4.1 g, p = 0.482, CI = -15.8, 7.6, d = 0.14; and (MD = 2.4 g, p = 0.791, CI = -19.9, 15.2, d = 0.13, respectively). Interestingly, the experienced group estimated protein intake to be higher than the actual value for the simple day (MD = 10.1 g, p = 0.027, CI = 2.1, 16.7, d = 0.50), but the inexperienced group did not (MD, 5.4 g, p = 0.070, CI = -2.2, 14.1, d = 0.38). When the whole sample was combined for the simple day, protein intake was estimated to be higher than the actual value (MD = 7.9 g, p = 0.009, CI = 2.1, 13.7, d = 0.44). Conversely, for the complex day protein intake estimates were lower than the actual values for the inexperienced (MD = -18.0 g, p = 0.011, CI = -31.5, -4.6, d = 0.51), experienced (MD = -15.7 g, p = 0.012, CI = -27.7, -3.7, d = 0.57) and whole sample (MD = -16.9 g, p < 0.001, CI = -25.7, -8.2, d = 0.54).

Meal by Meal Estimates

The complex day breakfast (figure 3A1-4) was underestimated for energy (MD = -0.63 MJ , p < 0.001, CI = -0.82, -0.45, d = 1.40, and MD = -0.50 MJ, p < 0.001, CI = -0.67, -0.34, d = 1.28) CHO (MD = -11.5 g, w = 325.0, z = 4.4, p < 0.001, r = 0.62, and MD = -11.5 g, w = 276.0, z = 4.2, p < 0.001, r = 0.62), and protein (MD = -22.1 g, p < 0.001, CI = -24.45, 1-.79, d = 3.90, and MD = -18.5 g, w = 276.0, z = 4.2, p < 0.001, r = 0.62) by the inexperienced and experienced groups. Notably the inexperienced group also underestimated the energy (MD = -

0.18 MJ, $p = 0.005$, $w = 267.0$, $z = 2.8$, $r = 0.40$), protein (MD = -3.5 g, $w = 240.0$, $z = 3.7$, $p < 0.001$, $r = 0.52$) and fat content (MD = -1.5 g, $w = 236.0$, $z = 3.7$, $p < 0.001$, $r = 0.51$) of the simple breakfast but this was not the case for the experienced group.

Typically, the simple snack energy (MD = -0.80 MJ, $w = 324.0$, $z = 4.4$, $p < 0.001$, $r = 0.62$, and 0.96 MJ, $p < 0.001$, CI = -1.11, -0.81, $d = 2.74$), CHO (MD = -12.6 g , $w = 324.0$, $z = 4.4$, $p < 0.001$, $r = 0.62$, and MD = -12.9 g, $w = 254.0$, $z = 3.5$, $p < 0.001$, $r = 0.52$) and fat (MD = 14.6 g, $w = 313.0$, $z = 4.1$, $p < 0.001$, $r = 0.57$, and MD = -15.8 g, $w = 276.0$, $z = 4.2$, $p < 0.001$, $r = 0.62$) content was underestimated by the inexperienced and experienced groups (figure 3B1-4). Conversely the inexperienced and experienced groups overestimated energy (MD = 0.29 MJ, $p = 0.001$, CI = 0.13-0.44, $d = 0.76$, and MD = 0.34 MJ, $w = 234.0$, $z = 2.9$, $p = 0.004$, $r = 0.43$), protein (MD = 7.9 g, $w = 295$, $z = 3.6$, $p < 0.001$, $r = 0.50$, and MD = 8.0 g, $w = 228.0$, $z = 2.7$, $p = 0.006$, $r = 0.40$) and fat (MD = 4.3 g, $w = 324.0$, $z = 4.3$, $p < 0.001$, $r = 0.62$, and MD = 4.4 g, $w = 272.0$, $z = 4.1$, $p < 0.001$, $r = 0.60$) for the complex snacks.

For the lunch meal, CHO content was underestimated by the inexperienced (MD = 10.2 g, $w = 290.0$, $z = 3.4$, $p < 0.001$, $r = 0.49$ and MD = -20.1 g, $p < 0.001$, CI = -28.9, -11.4, $d = 0.95$)

and experienced (MD = 7.9 g, $p = 0.001$, CI = 12.4, -3.4, d = 0.76 and MD = 16.1 g, $p < 0.001$, CI = -23.6, -8.6, d = 0.93) groups for both the simple and complex days respectively (figure 3 C1-4). The protein and fat content of the simple lunch were overestimated by the inexperienced (MD = 5.2 g, w = 253.0, z = 2.4, $p = 0.015$, r = 0.35 and MD = 11.5 g, w = 307.0, z = 3.9, $p < 0.001$, r = 0.55) and experienced (MD = 6.2 g, w = 222.0, z = 2.6, $p = 0.011$, r = 0.38, and MD = 21.1 g, w = 271.0, z = 4.0, $p < 0.001$, r = 0.60) groups, whereas the fat (MD = 4.3 g w = 324.0, z = 4.3, $p < 0.001$, r = 0.62 and MD = 7.1 g, w = 248.0, z = 3.4, $p < 0.001$, r = 0.49) and energy content (MD = -0.8 MJ, $p < 0.001$, CI = -1.1, -0.5, d = 1.21 and MD = -0.6 MJ, $p < 0.001$, CI = -0.8, -0.4, d = 1.25) of the complex lunch were underestimated by the inexperienced and experienced groups, respectively.

The energy (MD = 0.15 MJ, $p = 0.024$, CI = 0.02, 0.28, d = 0.48, and MD = 0.71 MJ, w = 271.0, z = 4.1, $p < 0.001$, r = 0.60), CHO (MD = 46.9 g, w = 325.0, z = 4.4 , $p < 0.001$, r = 0.62, and MD = 45.9 g, w = 276.0, z = 4.2, $p < 0.001$, r = 0.62) and protein content (MD = 5.0 g, $p = 0.004$, CI = 1.8, 8.1, d = 0.64, and MD = 3.0 g, w = 230.0, z = 2.8, $p = 0.005$, r = 0.41) of the simple evening meal (figure 3 D1-4) were overestimated, by the inexperience and experienced groups respectively. Additionally, the experienced group also overestimated the fat content for the simple (MD = 4.5 g, w = 256.0, z = 3.6, $p < 0.001$, r = 0.53) and the complex evening meal (MD = 18.6 g, w = 227.0, z = 2.7, $p = 0.006$, r = 0.40).

Assessment of Inter-Practitioner Reliability

The inter-practitioner reliability (Table 2 and Figure 2) was generally poor for the estimation of energy and nutrient intake. Specifically, the only acceptable inter-practitioner reliability was observed for the simple dietary intake day in both groups of practitioners, and the sample as a whole. All of the complex dietary intake day analysis resulted in poor or very poor inter-practitioner reliability. The inexperienced group appeared to have worse inter-practitioner reliability than their more experienced counterparts, but even the experienced practitioners displayed poor inter-practitioner reliability for energy intake and carbohydrate, and very poor reliability for fat and protein estimates. Furthermore, very poor inter-practitioner reliability was observed in both groups, and the sample as a whole, for estimates of fat and protein intake, with the exception of the experienced group's estimate of fat in the simple day, which was still poor.

DISCUSSION

The aim of the present study was to assess the validity of utilising the RFPM / 'Snap-N-Send' as a standalone methodology to assess energy and macronutrient composition. To this end, we recruited 49 accredited sport nutritionists to analyse two days of dietary images comprising four 'simple' meals or four 'complex' meals. We report that RFPM / 'Snap-N-Send' method has 'poor' validity compared with the known values for both total energy intake and macronutrient composition. Additionally, the inter-practitioner reliability was qualified as 'poor', even between the experienced sport nutritionists. Taken together, our data provide a reference point for practitioners when considering the typical error associated with these methods of dietary assessment.

The design of the present study allowed for 24 different assessments of validity (energy, carbohydrate, fat and protein; in complex and simple days; by experienced, inexperienced, combined nutritionists; 4x2x3). We report that only 8/24 of the assessments were qualified as 'adequate' with the remaining 16/24 categorised as 'poor' or 'very poor'. Moreover, no assessments of validity classed as 'good' or 'very good'. Overall, the RFPM / 'Snap-N-Send' method significantly underreported total energy content by 13% which is in line with previous research who have reported 8.8%, 11.3% and 13.1% respectively (Martin et al., 2012; Kikunga et al., 2007; Lassen et al., 2010). More importantly, however, was the extreme variation observed in the reporting of energy intake which ranged from -47% to +18%. Indeed, 'acceptable' validity for energy intake was only seen in the simple day when analysed by experienced practitioners and this still resulted in a TEE of -9.3%. These data are in contrast to the preliminary report assessing the validity of the ‘Snap-N-Send’ methodology where variability was reported as acceptable (<5%, Costello et al., 2017). It is noteworthy, however, that these researchers combined digital photography alongside a written food diary and all food items were weighed by the researcher team pre- and post-consumption. This contrasts with the present methodology where the individuals who performed the dietary assessments had no prior knowledge of the food being provided or portion sizes. As such, the data presented herein likely represent a more ecologically valid assessment scenario in which both practitioners and researchers are likely to engage in dietary assessment activities. Indeed, in a further study from Costello et al. (2019), the researchers compared ‘Snap-N-Send’ derived estimates of energy intake obtained from free living conditions (i.e. participants consumed their own food choices with no prior researcher knowledge) with energy expenditure (using doubly labelled water) and reported large random error and reduced measurement accuracy at an individual level. In this instance, the authors suggested that the poor performance of ‘Snap-N-Send’ was a consequence of low athlete adherence to submitting all of the food consumed. However, when considered with the present data, we suggest that it is likely due in part to the inability of practitioners to correctly identify foods and quantities from dietary photographs. Indeed, the limitation of using only one coder when performing dietary assessments is an important methodological factor considering the inherent variability that exists between experienced sports dieticians when coding food records for analysis (Braakhius et al., 2003). Our data could also suggest that the RFPM / Snap-N-Send, requires a high level of specialist and specific training prior to use in order to yield reliable data. We therefore suggest that in free living conditions, practitioners should take into consideration the limitations of this approach and interpret the data accordingly.

In addition to total energy intake, we also provide the first report of sport nutritionists using the RFPM / 'Snap-N-Send' methodology to assess the validity of analysing macronutrient composition. The validity of carbohydrate intake was 'poor' or 'very poor' in the experienced and inexperienced practitioners in both the simple and complex days with the range being as much as 75g-329g on one day. This 'poor' validity of carbohydrate intake is of particular concern given the majority of the meals, even on the complex day, used easily recognised carbohydrate sources such as potatoes. Many sport nutritionists now look to periodise carbohydrate intake based on the training of the athlete utilising the 'fuel for the work required' concept (Impey et al., 2018). The inability to accurately identify the amount of carbohydrate from dietary photographs (even on simple days by experienced practitioners) suggests that practitioners must be cautious with regards to making carbohydrate alterations to their athletes diets based purely upon pictures sent from their athletes. Protein intake was 'acceptable' with both inexperienced and experienced practitioners on the simple day however was 'poor' on the complex day ranging from 68-203 g. On the simple day, protein was easily identified with portion sizes easy to estimate through using foods such as poached eggs. However, on the more complex day, protein was in the form of scrambled eggs, a food harder to quantify via images alone. It is therefore crucial that in free living conditions practitioners are aware that significant error may exist in protein intake estimated from complex meals and advice should be tailored accordingly. Interestingly the most valid macronutrient estimate was for fat which was 'acceptable' in the experienced practitioners on both the simple and complex days. This may be due to the food choices being low fat meals, typically eaten by athletes, and future studies may wish to assess this observation in meals with a higher fat content.

In addition to quantifying total daily energy and macronutrient composition, we also performed analysis on a meal-by-meal basis. From a practical perspective, such analysis is highly important given that nutritional periodisation is performed on a meal-by-meal basis. In this regard, our data demonstrate extreme variability on a meal-by-meal basis with no consistent pattern of error in terms of the experience of practitioners, complexity, or type of meals. It did appear that the snacks where a particular problem with the complex snacks being over estimated for both energy and protein intakes in experienced as well as inexperienced practitioners. Given the high-reliance on snacks by athletes to achieve total caloric intakes, as well as to achieve suggested protein distribution (Areta et al., 2013) this over estimation of energy and protein could be a particular problem in athletic groups who often consume 3-4 snacks per day.

The present study also assessed the inter-practitioner reliability of RFPM / 'Snap-N-Send' in both the experienced and inexperienced sport nutritionists on the complex and simple days. With regards to the total energy intake, despite 'poor' validity, there was 'acceptable' reliability in both the inexperienced and experienced nutritionists on the simple food day, however this became 'poor' on the complex food day. Indeed, a CV of 20.2% and 15.4%, along with very low ICC's was reported on the complex day for the inexperienced and experienced nutritionists respectively. This pattern was also observed for carbohydrate intakes. Taken together these data suggest that when assessing anything apart from simple meals that are atypical of many athletes in free living conditions, the

RFPM / ‘Snap-N-Send’ methodology lacks inter-practitioner reliability even in experienced nutritionists. Given the lack of differences reported between the experienced and inexperienced sport nutritionists, our data suggests that experience in sport nutrition *per se* does not improve the accuracy of the RFPM / ‘Snap-N-Send’ methodology. Rather, sport nutritionists looking to use this technique would benefit from enhanced specialist training including targeted activities to address the components underpinning the accuracy in quantifying meal and individual food portions from pictures prior to use. It should be stressed, however, that taking pictures alongside traditional dietary intake methodologies could help to reduce participant burden, improve the accuracy of food diaries and help with behaviour change (Costello et al., 2019). It is therefore important not to dismiss the benefit of pictures to help with dietary assessment, rather the present data highlights the limitation of this technique as a standalone methodology.

Despite presenting novel data, this study is not without limitation, many of which are directly related to the controls employed to improve internal validity. Only two days of meals were analysed in an attempt to recruit high-performance nutritionists working in the elite environment. Initial conversations prior to testing suggested that this length of food diary would be acceptable from a time perspective for applied practitioners. Future studies may wish to assess more days with a wider range of energy intakes. Given that underreporting is further exacerbated in accordance with increases in total energy expenditure (Barnard et al., 2002) it is possible that in sports with higher energy intakes (e.g. rugby, Bradley et al., 2015), the RFPM / 'Snap-N-Send' could have higher variability than reported here. A second limitation is that the meals in the present study (despite some being classed as complex) were relatively plain with things such as sauces and deserts being left to a minimum. Combined with the fact that it was not necessary to account for uneaten food, there is a high possibility that when used by athletes in the field as an assessment tool, the variability could be more extreme than reported in the current data. Likewise, the present study was based upon the diet histories reporting 100% of the total food consumed. In the real-world it is likely that athletes will forget to take pictures (or fail to submit) all of the food and drinks consumed adding further error to this method. The present study used only one dietary assessment software (Nutritics) given that Nutritics is widely used in sport nutrition in the UK and Ireland (where all participants were based) and were familiar with the software using it regularly in their daily jobs. To assess whether the error reported was purely related to the software, the lead researcher with specific knowledge of the foods and weights inputted all of the data into Nutritics and gained values within 1% of the total energy reported on the food labels, suggesting that the error was not within the software but rather the interpretation of the food from the pictures. Finally, the aim of the present study was to assess the RFPM / 'Snap-N-Send' within sport nutrition and it therefore cannot be excluded that specialist trained individuals who are highly experienced in picture-based diet assessments may achieve differing data to that reported in the present study.

In conclusion, we provide the first report to assess the validity of the RFPM / 'Snap-N-Send' as a standalone methodology to assess energy and macronutrient composition of dietary photographs. Our data demonstrate 'poor' validity and inter-practitioner reliability, even when dietary analysis was performed by experienced sport nutritionists. The present data therefore provide a reference point for practitioners when considering the typical error associated with these methods of dietary assessment. Such estimates of validity should therefore be taken into account when utilising this method alongside the requirement to use multiple coders when performing dietary analysis of athletic populations.

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The study was designed by RGS, AMK, JPM and GLC; data were collected and analysed by RGS, GLC and SAS; data interpretation and manuscript preparation were undertaken by

RGS, AMK, SAS, JPM and GLC. All authors approved the final version of the paper.

REFERENCES

Areta, J.L., Burke, L.M., Ross, M.L., Camera, D.M., West, D.W.D., Broad, E.M., Jeacoake, N.A., Moore, D.R., Stellingwerff, T., Phillips, S.M., Hawley, J.A., & Coffey, V.G. (2013). Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. *The Journal of Physiology, 591, 9,* 2319-2331.

Barnard, J.A., Tapsell, L.C., Davies, P.S.W., Brenninger, V.L., & Storlien, L.H. (2002). Relationship of high energy expenditure and variation in dietary intake with reporting accuracy on 7 day food records and diet histories in a group of healthy adult volunteers. *European Journal of Clinical Nutrition, 56,* 358-367.

Braakhuis, A.J., Meredith, K., Cox, G.R., Hopkins, W.G., & Burke, L.M. (2003). Variability in estimation of self-reported dietary intake data from elite athletes resulting from coding by different sports dieticians. *International Journal of Sport Nutrition & Exercise Metabolism, 13,* 152-165.

Bradley, W.J., Cavanagh, B., Douglas, W., Donovan, T.F., Twist, C., Morton J.P., & Close, G.L. (2015). Energy intake and expenditure assessed ‘in-season’ in an elite European rugby union squad. *European Journal of Sport Science, 15,* 469-479.

Burke, L.M., & Hawley, J.A. (2018). Swifter, higher, stronger: What’s on the menu? *Science, 362*, 781-787.

Capling, L., Beck, K.L., Gifford, J.A., Slater, G., Flood, V.M., & O’Connor, H. (2017). Validity of dietary assessment in athletes: A systematic review. *Nutrients, 9*, 1313.

Cook, J.A., Hislop, J., Adewuyi, T.E., Harrild, K., Altman, D.G., Ramsay, C.R., Fraser, C., Buckley, B., Fayers, P., Harvey, I., Briggs, A.H., Norrie, J.D., Fergusson, D., Ford, I., & Vale, L.D. (2014). Assessing methods to specify the target difference for a randomised controlled trial - DELTA (Difference ELicitation in TriAls) review. *Health Technology Assessment*, 18(28).

Costello, N., Deighton, K., Dalton-Barron, N., Whitehead, S., Preston, T., & Jones, B. (2019). Can a contemporary dietary assessment tool or wearable technology accurately assess the energy intake of professional young rugby league players? A doubly labelled water validation study. *European Journal of Sport Science*, *Online ahead of print.*

Costello, N., Deighton, K., Dyson, J., McKenna, J., & Jones, B. (2017). Snap-n-Send: A valid and reliable method for assessing the energy intake of elite adolescent athletes. *European Journal of Sport Science*, *1044-1055.*

Gemming, L., Utter, J., & Ni Mhurchu, C. (2014). Image-assisted dietary assessment: A systematic review of the evidence. *Journal of the Academy of Nutrition & Dietetics, 115,* 64-77.

Hannon, M., Carney, D., Floyd, S., Parker, L.J.F., McKeown, J., Drust, B., Unnithan, V., Close, G.L., & Morton, J.P. (2020). Cross-sectional comparison of body composition and resting metabolic rate in Premier League academy soccer players: Implications for growth and maturation. *Journal of Sports Sciences, EPub.*

Impey, S.G., Hearris, M.A., Hammond, K.M., Bartlett, J.D., Louis, J., Close, G.L., & Morton, J.P. (2018). Fuel for the work required: A theoretical framework for carbohydrate periodisation and the glycogen threshold hypothesis. *Sports Medicine, 48,* 1031-1048.

Kasper, A.M., Crighton, B., Langan-Evans, C., Riley, P., Sharma, A., Close, G.L., & Morton, J.P. (2018). Case study: Extreme weight making causes relative energy deficiency, dehydration and acute kidney injury in a male mixed martial arts athlete. *International Journal of Sport & Exercise Metabolism, 29,* 1-20.

Kikunaga, S., Tin, T., Ishibashi, G., Wang, D.H., & Kira, S. (2007). The application of a handheld personal digital assistant with camera and mobile phone card (Wellnavi) to the general population in a dietary survey. *Journal of Nutritional Science & Vitaminology, 53,* 109-116.

Kirkpatrick, S.I., & Collins, C.E. (2016). Assessment of nutrient intakes: Introduction to the special issue. *Nutrients, 8,* 184.

Lassen, A.D., Poulsen, S., Ernst, L., Andersen, K.K., Biltoft-Jensen, A., & Tetens, I. (2010). Evaluation of a digital method to assess evening meal intake in a free-living adult population. *Food & Nutrition Research, 54,* 1-9.

Livingstone, M.B.E., & Black, A.E. (2003). Markers of the validity of reported energy intake. *The Journal of Nutrition, 133,* 895S-920S.

Martin, C.K., Correa, J.B., Han, H., Allen, H.R., Rood, J., Champagne, C.M., Gunturk, B.K., & Bray, G.A. (2012). Validity of the remote food photography method (RFPM) for estimating energy and nutrient intake in near real-time. *Obesity (Silver Spring), 20,* 891-899.

Martin, C.K., Kaya, S., & Gunturk, B.K. (2009). Quantification of food intake using food image analysis. *Conference Proceedings: Annual International Conference of the IEEE Engineering in Medicine and Biology Society,* 6869-6872.

Morton, J.P., Robertson, C., Sutton, L., & MacLaren, D.P.M. (2010). Making the weight: A case study from professional boxing. *International Journal of Sport Nutrition & Exercise Metabolism, 20,* 80-85.

Rollo, M.E., Williams, R.L., Burrows, T., Kirkpatrick, S.I., Bucher, T., & Collins, C.E. (2016). What are they really eating? A review on new approaches to dietary intake assessment and validation. *Current Nutrition Reports, 5,* 307-314.

Thompson, F.E., Subar, A.F., Loria, C.M., Reedy, J.L., & Baranowski, T. (2010). Need for technological innovation in dietary assessment. *Journal of the American Dietetic Association, 110,* 48-51.

Walsh, N.P. (2019). Nutrition and athlete immune health: New perspectives on an old paradigm. *Sports Medicine, 49,* 153-168.

Westerterp, K.R., Saris, W.H., Van Es, M., & Ten Hoor, F. (1986). Use of the doubly labeled water technique in humans during heavy sustained exercise. *Journal of Applied Physiology, 61*, 2162-2167.

Wilson, G., Drust, B., Morton, J.P., & Close, G.L. (2014). Weight-making strategies in professional jockeys: Implications for physical and mental health and well-being. *Sports Medicine, 44*, 785-796.

Wilson, G., Pritchard, P.P., Papageorgiou, C., Phillips, S., Kumar, P., Langan-Evans, C., Routledge, H., Owens, D.J., Morton, J.P., & Close, G.L. (2015). Fasted exercise and increased dietary protein reduces body fat and improves strength in jockeys. *International Journal of Sports Medicine, 36*, 1008-1014.

FIGURE & TABLE LEGENDS

Figure 1. Overview of diet diary provided for both simple and complex days. This includes image and brief explanation provided to participants (**non-italic**) alongside the calculated energy and macronutrient breakdowns for each meal and overall daily total may (**italics**). Mega joules, MJ; carbohydrate, CHO; protein, PRO; and fat, FAT.

Table 1. Outcomes of the limits of agreement (LoA) and coefficient of variation (CV) analysis. CI denotes 95% Confidence interval.

Table 2. Outcomes of the inter-rater reliability analysis. (α): Cronbach's alpha; (ICC): intra class correlation; (CI): 95% confidence interval; (CV): coefficient of variation.

Figure 2. Total energy intake (**A**) estimated by inexperienced (**black circles**) and experienced (**white circles**) accredited practitioners on the simple and complex days. Macronutrient intake estimated by practitioners for carbohydrate (**B**), protein (**C**) and fat (**D**). Bars are representative of mean estimation with the dashed line representing actual calculate energy intake for energy. * represents a significant difference compared to actual calculated intake. # indicates significant differences between groups.

Figure 3. Meal by meal overview (**A**, Breakfast; **B**, Snack; **C**, Lunch; **D**, Evening meal) of total energy, carbohydrate, protein and fat content (**1-4** respectively) estimated by inexperienced (**black circles**) and experienced (**white circles**) accredited practitioners on the simple and complex days. * represents a significant difference compared to actual calculated intake.

FIGURE & TABLES

Figure 1.

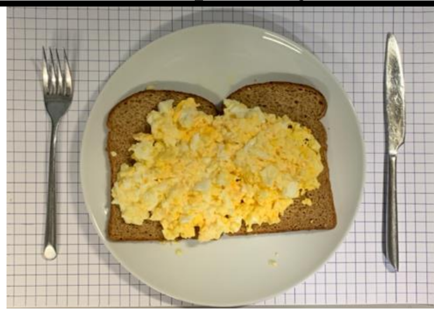
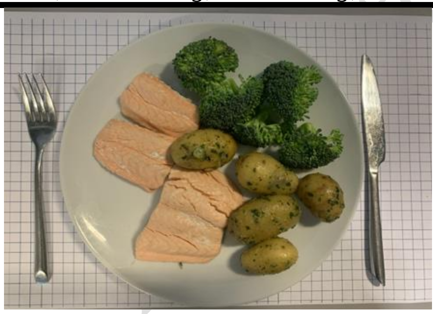
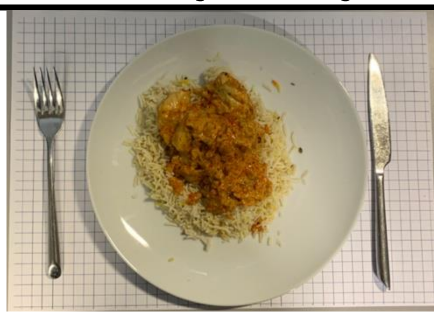
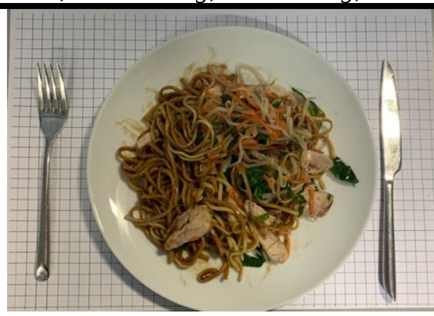
	Simple Day	Complex Day
Breakfast	 Weetabix cereal (made with semi-skimmed milk) [*MJ=1.08; CHO=39.5g; PRO=13.5g; FAT=5.1g*]	 Scrambled eggs on toast (made with semi-skimmed milk) [*MJ=2.50; CHO 41.3g; PRO 45.3g; FAT 28.2g*]
Morning Snack	 Avocado on toast with poached eggs [*MJ=3.19; CHO=44.0g; PRO=25.6g; FAT=53.7g*]	 Overnight oats (made with chocolate milk and whey protein) [*MJ=1.56; CHO=55.0g; PRO=26.7g; FAT=4.8g*]
Lunch	 Poached salmon with baby new potatoes and broccoli [*MJ= 2.49, CHO=34.7g; PRO=47.8g; FAT=26.0g*]	 Chicken tikka masala with pilau rice [*MJ=2.48; CHO=62.1g; PRO=35.6g, FAT 20.4g*]
Evening Meal	 Chicken breast fillet with basmati rice and mixed peppers [*MJ=2.57; CHO=94.9g; PRO=41.0g; FAT=4.4g*]	 Chicken chow mein [*MJ= 1.99; CHO=49.2g; PRO=32.8g; FAT=15.2g*]
Total	***MJ=9.33; CHO=213.1g; PRO=127.9; FAT=89.2g***	***MJ=8.53; CHO=207.6g; PRO=140.4; FAT=68.6g***

Table 1.

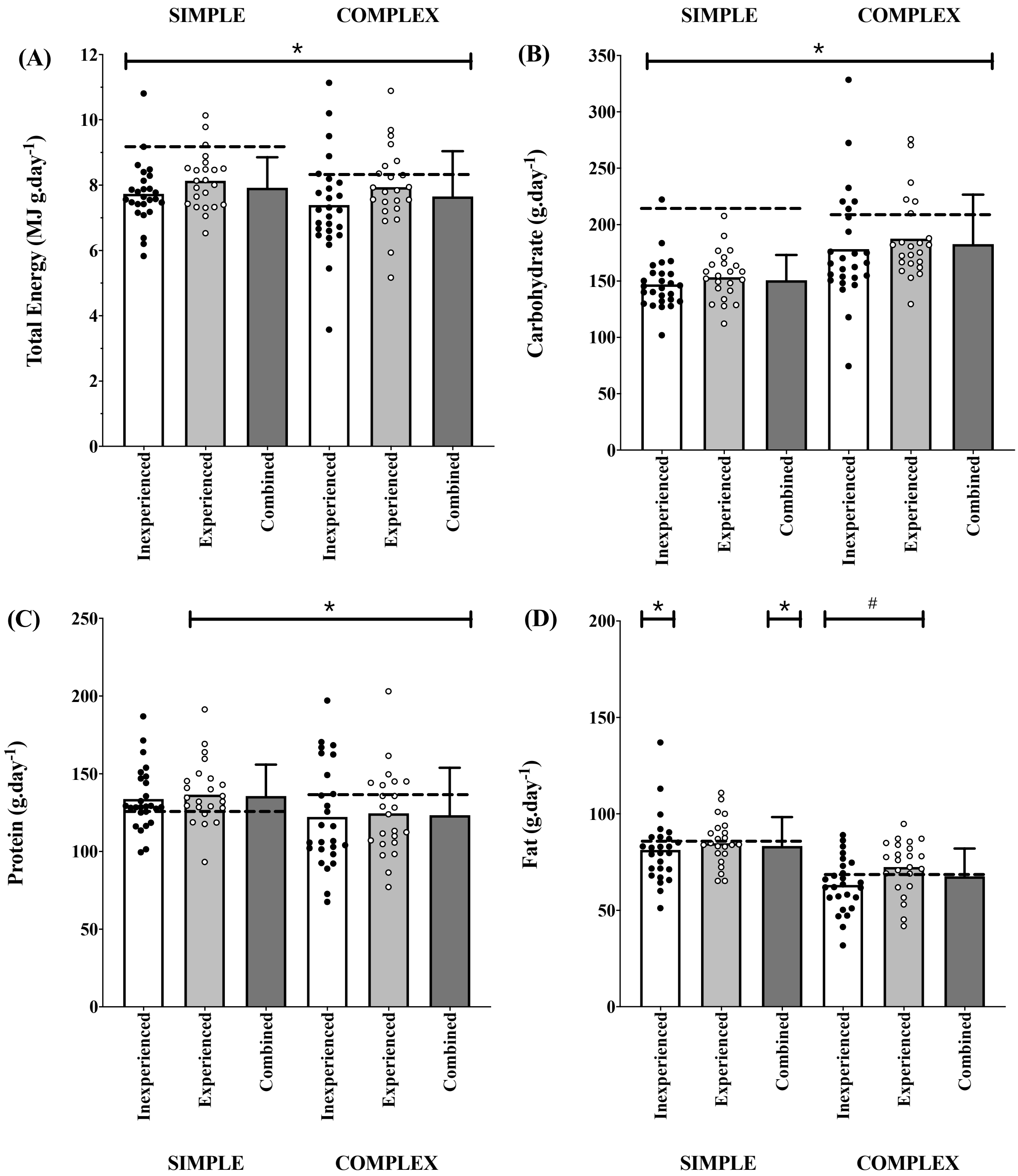
Dietary Variable	Inexperienced		Experienced		All	
	Simple	**Complex**	**Simple**	**Complex**	**Simple**	**Complex**
Daily Energy Intake (MJ)						
Bias	-1.5	-1.2	-1.2	-0.6	-1.4	-0.9
CI	-1.9, -1.2	-1.8, -0.5	-1.6, -0.8	-1.2, 0.1	-1.6, -1.1	-1.3, -0.5
LoA (upper)	0.3	1.8	5.0	1.8	0.4	1.8
LoA (lower)	-3.4	-4.3	-0.5	-3.0	-3.2	-3.7
CV (%)	10.1	17.8	9.3	14.3	9.8	16.4
Interpretation	Poor	Poor	Acceptable	Poor	Poor	Poor
Carbohydrate ($g.day^{-1}$)						
Bias	-65.5	-28.7	-53.4	-19.9	-62.6	-24.5
CI	-75.0, -56.0	-49.7, -7.8	-62.7, -44.0	-35.6, -4.2	-68.8, -55.8	-37.3, -11.6
LoA (upper)	-20.5	70.7	-7.5	51.7	-19.1	62.1
LoA (lower)	-110.5	-128.1	-110.2	-91.4	-106.1	-110.6
CV (%)	10.8	24.4	10.1	17.5	10.4	21.3
Interpretation	Poor	Very Poor	Poor	Poor	Poor	Very Poor
Fat ($g.day^{-1}$)						
Bias	-7.1	-5.8	-3.6	4.0	-5.8	-1.1
CI	-14.2, 0.0	-11.6, 0.0	-8.8, 1.7	-2.0, 9.9	-9.7, -1.1	-5.4, 3.1
LoA (upper)	26.5	21.7	20.2	31.0	23.7	27.5
LoA (lower)	-40.8	-33.2	-27.3	-23.0	-35.2	-29.7
CV (%)	19.3	20.4	5.7	6.6	7.1	7.0
Interpretation	Poor	Very Poor	Acceptable	Acceptable	Acceptable	Acceptable
Protein ($g.day^{-1}$)						
Bias	7.3	-17.2	10.1	-15.7	7.9	-16.5
CI	-0.6, 15.3	-31.2, -3.3	1.28, 18.9	-27.7, -3.7	2.9, 14.3	-25.4, -7.6
LoA (upper)	45.2	49.0	49.9	38.5	47.4	43.7
LoA (lower)	-30.5	-83.5	-29.7	-69.9	-31.6	-76.7
CV (%)	9.1	16.3	9.5	13.3	9.5	14.8
Interpretation	Acceptable	Poor	Acceptable	Poor	Acceptable	Poor

Table 2.

α: Cronbach's alpha; ICC: intra class correlation; CI: 95% confidence interval; CV: coefficient of variation.

	Inexperienced		Experienced		All	
Dietary Variable	**Simple**	**Complex**	**Simple**	**Complex**	**Simple**	**Complex**
Daily Energy Intake						
α	0.985	0.931	0.977	0.834	0.991	0.950
ICC	0.73	0.35	0.65	0.180	0.69	0.29
CI	0.32, 1.00	0.06, 1.00	0.23, 1.00	0.001, 0.99	0.29, 1.00	0.06, 1.00
CV (%)	12.1	20.6	10.7	15.4	11.5	18.3
Interpretation	Acceptable	Poor	Acceptable	Poor	Acceptable	Poor
Carbohydrate						
α	0.995	0.875	0.994	0.855	0.997	0.932
ICC	0.89	0.22	0.88	0.20	0.89	0.22
CI	0.60, 1.00	0.02, 0.99	0.57, 1.00	0.12, 0.99	0.60, 1.00	0.04, 1.00
CV (%)	15.6	28.6	14.0	19.3	14.8	24.1
Interpretation	Acceptable	Very Poor	Acceptable	Poor	Acceptable	Poor
Fat						
α	0.765	0.765	0.496	0.472	0.841	-2.562
ICC	0.12	0.12	0.04	0.04	0.10	-0.02
CI	-0.01, 0.99	-0.01, 0.99	-0.03, 0.99	-0.03, 0.99	0.04, 0.99	-0.02, 0.85
CV (%)	20.9	22.3	14.1	19.0	17.8	21.6
Interpretation	Very Poor	Very Poor	Poor	Very Poor	Very Poor	Very Poor
Protein						
α	0.722	0.846	0.823	0.865	0.892	0.928
ICC	0.09	0.18	0.17	0.218	0.15	0.21
CI	-0.01, 0.99	0.01, 1.00	0.002, 0.99	0.16, 0.99	0.02, 1.00	0.03, 1.00
CV (%)	14.3	27.4	14.7	22.2	14.4	24.8
Interpretation	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor

Figure 2.


SIMPLE
COMPLEX
(A)
Total Energy (MJ g.day-1)
(B)
Carbohydrate (g.day-1)
(C)
Protein (g.day-1)
(D)
Fat (g.day-1)
Inexperienced
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Combined
Inexperienced
Experienced
Combined
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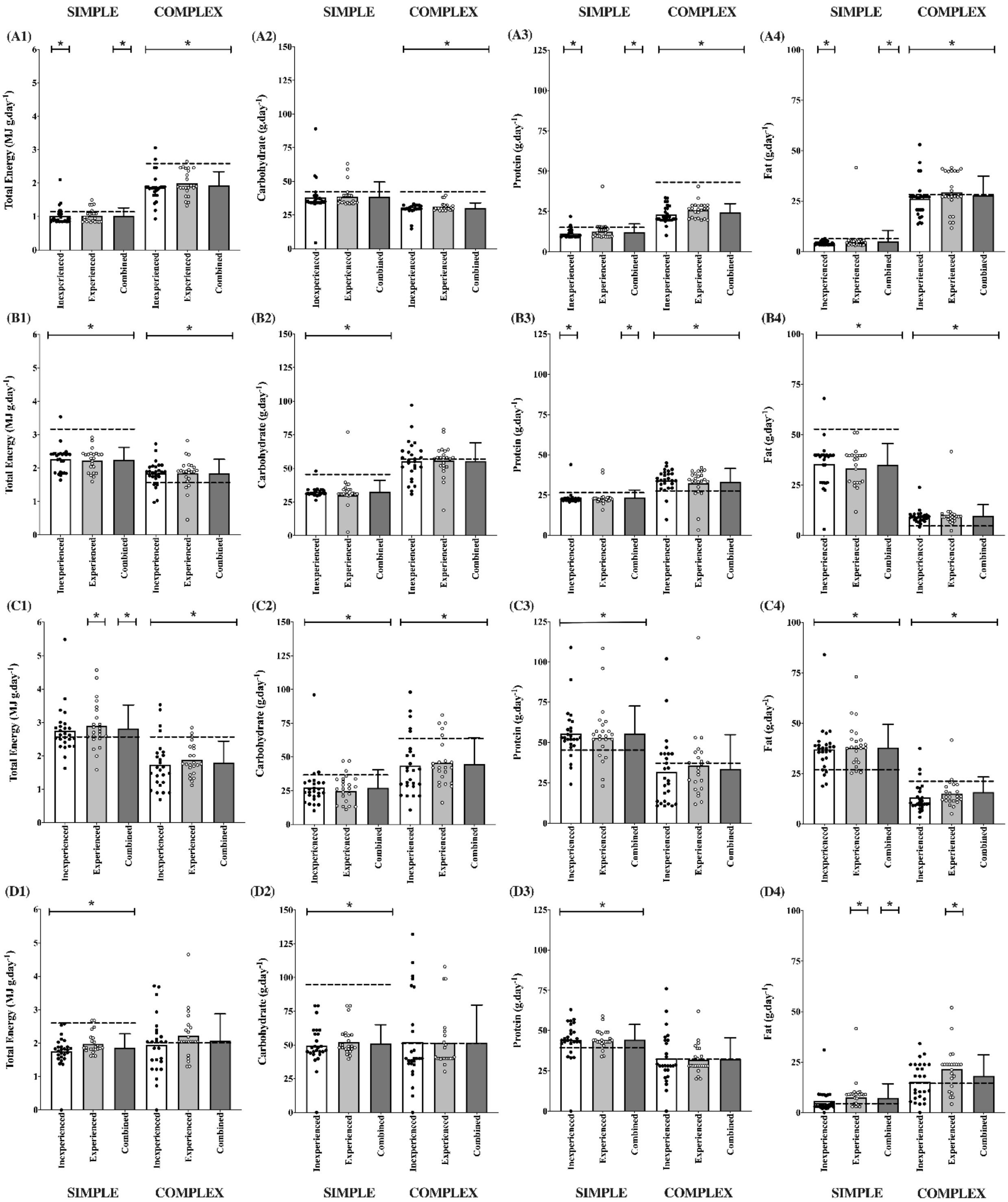
Figure 3.


SIMPLE
COMPLEX
(A1)
(A2)
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(D3)
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Total Energy (MJ g.day-1)
Carbohydrate (g.day-1)
Protein (g.day-1)
Fat (g.day-1)
Inexperienced
Experienced
Combined